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PRELIMINARY REPORT

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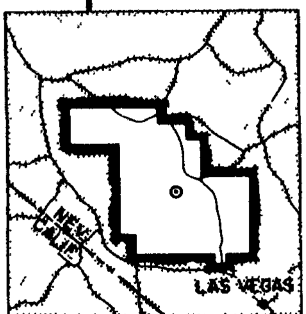

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MAY-OCTOBER 1957

Project 32.4

FALLOUT STUDIES AND ASSESSMENT OF RADIOLOGICAL PHENOMENA

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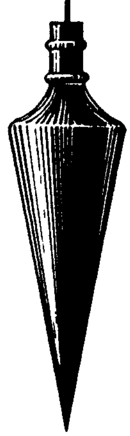

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Operation PLUMBBOB Preliminary Report

Project 32.4

FALLOUT STUDIES AND ASSESSMENT OF RADIOLOGICAL PHENOMENA

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November 1957

ABSTRACT

Data were obtained to evaluate the attenuation of photons, emitted from a fallout field, due to the surface roughness of the terrain.

A study was made to determine the effect of the shot tower on the fallout material. Particles for comparison were collected from two detonations of equal scaled height, one tower supported the other balloon supported.

Documentary support of the fallout phenomena was accomplished for Project 32.3 about their radiological shelter. Data on time-dependent phenomena were recorded, as were physical characteristics of the fallout material.

The use of small balloons as instrument platforms and a new fall-out collector were evaluated for field use.

No conclusions or recommendations can be made at this time.

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Chapter 1

OBJECTIVES

The objectives of this project were to (1) study the terrain attenuation factor for gamma fields; (2) study the effect of shot towers on the physical, chemical, and radiochemical features of fall-out material; (3) provide documentary support to Project 32.3; and (4) field test prototype instrumentation developed for the collection of countermeasures data.

Chapter 2

TERRAIN ATTENUATION FACTOR

2.1 BACKGROUND

Under present theory, if the absolute photon emission rate from a smooth plane and the gamma-energy spectrum of the photons are known, the gamma-field intensity at any height above this plane can be calculated[1]. Such calculations are frequently used in the reduction of field data when it is desired to know from the gamma-field measurements the quantity or fraction of the device deposited in that area[2]. These conversions for a real or rough surface require a correction for the attenuation of gamma activity by the soil surface. This attenuation effect was first demonstrated at Operation Jangle[3]. Subsequent studies were made[4] using data obtained for other purposes at later test operations; however, certain pertinent data requirements were missing, and thus the quality of the results obtained left the conclusions questionable. Measurement of all necessary parameters was attempted at Operation Plumbbob to increase the accuracy of such an experimentally determined correction factor.

2.1.1 Theory

Shielding against gamma radiation from fallout deposited on a rough surface has been described as analogous to mixing or burial of the emitters to a given depth[5]. Use of such an analog allows computation of the magnitude of these effects on the ionization rate from an extended radiation source. Thus the gamma intensities for various depths of mixing or burial can be compared with the calculated values for a smooth plane. These hypothetical mathematical analogs have not been adequately demonstrated by experiment. An evaluation of them can be made by measurement of the gamma field produced by fallout from a nuclear detonation. Experimental data that will determine the attenuation factor for a given real surface can be used to test the analog models. Should experimental data agree with theory or allow a refinement of the theoretical approach, then extrapolation to other surface conditions may be possible.

By determining the absolute photon emission rate of the deposited material, one can calculate, using the methods derived for a smooth plane, the absolute ionization rate at some height above this plane. This calculated value can then be directly compared with a precise measurement of the actual ionization rate over the fallout area at the same height. The difference between the measured reading and that calculated will be a measure of the reduction due to attenuation by surface irregularities.

Another method for determining the effect of terrain on radiation intensity may be possible: It is assumed that when measurements of gamma ionization are made at heights much greater than 3 ft the effect of soil attenuation is minimized as the measuring instrument approaches the altitude where the gamma photons seen are primarily normal to the earth's surface. Therefore at some altitude the calculated intensity values for a smooth plane should approach the intensity values over a rough plane. If this is true, the evaluation can be accomplished without determining the absolute photon emission rate per unit area by simply taking relative readings as a function of altitude at a time when the gamma-energy spectrum of the source is known. Then, by assuming a photon emission rate of say 10^6 photons/sec/sq ft and using the computations of Werner[6] and Van Lint[7], one can determine for the measured spectrum the ionization in milliroentgens per hour as a function of altitude. This calculated curve can be compared to the measured data by normalizing at an altitude above which the ratio of calculated to measured is a constant. The ratio of the measured value at 3 ft to that calculated for 3 ft will be a determination of the terrain attenuation factor. Comparison of this approach to the absolute method will determine whether absolute radiation measurements need be made or whether the only requirement is that the measurements be relative to each other.

2.2 PROCEDURE

Major participation for Project 32.4 was in event Shasta. Limited studies were attempted in events Priscilla and Diablo.

2.2.1 Event Shasta

On the morning of D + 2 a satisfactorily flat radiation field was found in the vicinity of the Project 32.3 radiological shelter. This underground shelter became the center of a 1000-ft-radius 43-point gamma survey made at a height of 3 ft. A AN/PDR/T1B survey meter was used which had been calibrated with a set of Co^{60} standards the day of the measurements. At each of the 43 points the meter was first zero set; four readings were then taken at azimuths 90 deg apart.

Coincident with this survey, a fallout sample collected over 3 sq ft at the center of the circular area was being analyzed at the USNRDL to determine, by gamma spectroscopy, the absolute photon emission rate per unit area[8] emanating from the fallout radiation field within the area. The sample had been collected in the open-close collector installed on the top of the shelter.

Also during the morning of D + 2, a determination of radiation intensity as a function of height above the center of the area was made. Measurements were taken from a helicopter by suspending the same survey meter employed in the surface measurements 1 ft below the aircraft. Readings were taken at 100-ft intervals from 100 to 1500 ft above the surface.

Documentary photographs of the area were taken to define the roughness of the terrain for comparison with other soil types and surface environments.

2.2.2 Events Priscilla and Diablo

Limited studies made on these detonations employed the same techniques described for event Shasta with the exception that few measurements above an altitude of 3 ft were obtained. Attempts were made to suspend instruments from latex balloons, having a free lift of approximately 25 pounds, to obtain gamma-intensity measurements as a function of altitude. The survey meter, equipped with remote readout, was suspended from the balloon harness. The meter was raised to predetermined heights, and readings were taken via a cable to a remote meter on the ground. Because of adverse wind conditions and the delicate nature of the balloons, this phase of the study failed. In lieu of the balloons a 60-ft boom crane was used on shot Diablo.

There was no instrumentation in the radiation fields chosen for these two events, and samples used for gamma spectral analysis were obtained by taking soil samples.

2.3 RESULTS

2.3.1 Event Shasta

Figure 2.1 shows the gamma-radiation contours over the area studied. Readings (milliroentgens per hour) were made with AN/PDR/T1B-146 survey meter. Four readings were taken at each point, the meter being zero set before each set of readings. In no case did any of these individual readings at any one point vary by more than 5 mr/hr. This amounts to a variation of from 2.5 to 5 per cent. Measurements are listed in Table 2.1.

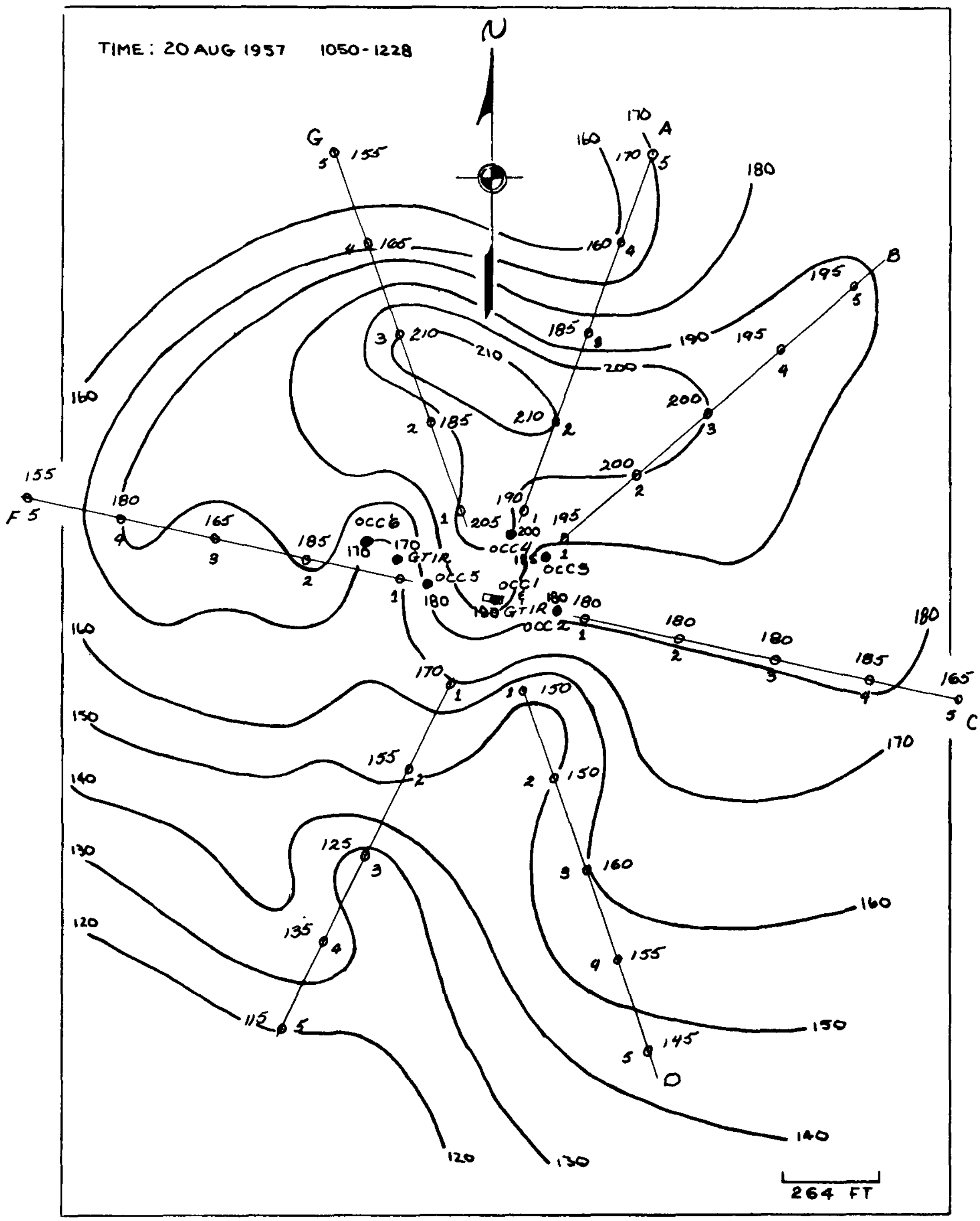

Fig. 2.1--Gamma radiation contours about NRDL shelter.

Table 2.1--GAMMA-RADIATION SURVEY AT 3 FT AROUND RADIOLOGICAL SHELTER

Station	Level at 3 ft, mr/hr	Time 20 Aug. 1957	Station	Level at 3 ft, mr/hr	Time 20 Aug. 1957
OCC #1	190	1050	D-1	150	1142
OCC #2	180	1055	D-2	150	1143
OCC #3	185	1053	D-2	160	1145
OCC #4	200	1051	D-4	155	1147
OCC #5	180	1057	D-5*	145	1148
GTIR (field)	170	1059	E-1	170	1155
OCC #6	170	1100	E-2	155	1157
Rad. stake: N879 E663.5	175	1057	E-3	125	1200
A-1	190	1105	E-4	135	1200
A-2	210	1107	E-5	115	1202
A-3	185	1109	F-1**	180	1206
A-4	160	1112	F-2	185	1207
A-5	170	1114	F-3	165	1210
B-1	195	1118	F-4	180	1213
B-2	200	1120	F-5	155	1215
B-3	200	1122	G-1	205	1221
B-4	195	1124	G-2	185	1223
B-5	195	1125	G-3***	210	
C-1	180	1130	G-4	165	1226
C-2	180	1121	G-5	155	1228
C-3	180	1133			
C-4	185	1135			
C-5	165	1137			

*Rad Safe Survey Stake N-878-E 664.
**Near TIR.
***Center of 1000-ft smoothed circle.

The terrain characteristics of the measured area were typical of Nevada desert, consisting of rocky soil covered with scrub brush to heights of 2 ft. Occasional dry washes were observed.

Table 2.2 lists the measurements made over the selected area as a function of altitude. These measurements have been corrected for altitude above the surface. The shelter was located at an elevation of 4540 ft above mean sea level. All readings were taken with survey meter AN/PDR/T1B-146, the meter being zero set before each measurement.

Measurement of the absolute photon emission rate per unit area from the fallout field has not been reduced to date. Final reduction of these data and their subsequent analysis for determination of the terrain attenuation factor will be found in the final report.

2.3.2 Events Priscilla and Diablo

No suitable flat gamma field could be found after shot Priscilla. Because of the steep gradients it was decided not to attempt to make this study on this shot.

On shot Diablo a flat fallout field was located on D + 5 and measurements were made with some variation of the technique employed on Shasta.

A 200-ft-diameter circular area was surveyed with a calibrated AN/PDR/T1B survey meter at a height of 3 ft. Gamma measurements varied from a minimum of 265 mr/hr to a maximum of 285 mr/hr. Terrain characteristics of the area measured were similar to those found on the Shasta experiment and described in Sec. 2.3.1.

Since no helicopter was available, a 60-ton boom crane was used, and measurements as a function of altitude were made from the boom of this crane after locating it in the center of the surveyed area. Two runs were made, one with the boom facing west and one with the boom facing east (Table 2.3).

Field measurements were made on the afternoon of D + 5. At 1600 on the same day gamma spectral measurements were run on four soil samples, each taken over a 1-sq ft area. Reduction of the soil-sample spectra to absolute photon emission rate has not been accomplished to date. Final reduction of these data and their subsequent analyses for the determination of the terrain attenuation factor will be found in the final report.

Table 2.2--GAMMA IONIZATION MEASUREMENTS AS A FUNCTION OF ALTITUDE OVER RADIOLOGICAL SHELTER

Height above ground, ft	Gamma intensity, mr/hr	Time 20 Aug. 1957
1660	2.1	0855
1560	3.0	0856
1460	3.5	0858
1360	4.0	0900
1260	5.2	0902
1160	7.0	0903
1060	8.0	0904
960	12.0	0905
860	15.0	0907
760	19.0	0908
660	23.0	0850
660	23.0	0910
660	23.0	0919
560	26.0	0911
460	36.0	0912
360	50	0914
260	80	0915
160	120	0916

Table 2.3--MEASUREMENT OF GAMMA RADIATION AS A FUNCTION OF ALTITUDE OVER SHOT DIABLO FALLOUT FIELD

Height ft	Boom direction East, mr/hr	West, mr/hr
3	275	270
10	290	235
20	255	210
30	215	205
40	205	200
50	180	200
58	180	190

2.4 DISCUSSION

The experimental phase on shot Shasta offers the best data for analysis. The instrument used was calibrated, and reproducible results were obtained. Measurements of activity as a function of altitude taken from the helicopter need not be corrected for shielding because the meter was suspended 1 ft below the aircraft hull, seeing an unobstructed 2-pi solid angle. All necessary measurements required for the final analysis, including the spectral data, were taken within 4 hr of each other, thereby assuring compatibility of the radiation survey measurements with the spectral measurements.

The expected results from shot Diablo may prove less valid because of the effect of the boom crane on the measurements. Also, instrument drift affected the reproducibility of the measurements as a function of altitude to some degree.

2.5 CONCLUSIONS AND RECOMMENDATIONS

No conclusions or recommendations can be made at this time.

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Chapter 3

EFFECT OF SHOT TOWERS ON THE NATURE OF FALLOUT PARTICLES

3.1 BACKGROUND

A large majority of the continental test detonations from which fallout has been documented and on which fallout models have been developed have been fired from steel towers. At Operation Plumbbob the use of balloon-supported detonations gave an opportunity for a comparison of the physical, chemical, and radiochemical composition of the fallout particles from a true low air burst (balloon detonated) with that from a tower shot. The results of such an investigation should describe the nature of the fallout from an operational near-surface burst, which, in turn, may improve the development of a fallout model for such a detonation.

3.1.1 Theory

A knowledge of the source of fallout particles is mandatory for an adequate understanding of the mechanism of fallout[1] as well as for the development of reclamation procedures[2]. The inclusion of foreign materials in the fireball, such as shot-tower iron, may influence the characteristics of the fallout particles. Such particles, through differences in size, shape, and chemical characteristics, will influence the presently developed theories on fallout formation and deposition.

For comparison purposes two shots of equal scaled height, one tower supported and one balloon supported, are required. The influence of a shot-tower-free environment can be determined by collecting and analyzing fallout particles from these detonations.

3.2 PROCEDURE

On-site fallout was collected from shots Priscilla, Diablo, Shasta, and Owen. Priscilla and Owen were balloon-supported shots, and Diablo and Shasta were tower shots.

3.2.1 Instrumentation

Two types of ground-level collector were employed in the field. The open-close collectors (OCC)3 consisted of a framework, with sliding cover, holding a polyethylene-lined tray 3 sq ft in area and 2 in. deep. There was an epoxy-coated hexcell liner in the tray perforated with hexagonal openings 3/4 in. in diameter. The liner prevented the collected fallout material from being affected by the wind. The sliding cover was operated from a self-contained supply of compressed air. Each instrument was installed flush with the surface to ensure maximum efficiency of collection and to eliminate bias due to projections in the air stream.

The collectors were timed to open at zero time by an EG&G Mark IV Blue Box, backed up by a Giannini pressure trigger, type 44518. A time-delay mechanism closed the covering lid at H + 1 hr, thereby sealing the collected material until recovered.

The always-open collectors (AOC)3 were identical in collecting area and installation; however, they had no covering mechanism and remained exposed from the time when last checked and cleaned to recovery.

Recovery of all samples consisted in removing the collecting tray and covering it with a polyethylene lid taped in place. The trays were then transported to the Project's forward-area trailer, where they were banded and boxed for shipment in special cartons.

3.2.2 Sampling Array

The locations of the samplers were predetermined from fallout predictions and off-site safe firing requirements supplied by the Test Organization. Station arrays for the four shots are shown in Figs. 3.1 and 3.2. The relation of the collectors to the measured fallout field is also indicated by superimposing the Test Organization Rad-Safe surveys for each of these detonations on the station array diagrams.

3.2.3 Disposition of Samples

Samples from each shot were collected as early as H + 1 hr and shipped to the USNRDL from Indian Springs by special carrier aircraft.

3.2.4 Sample Analysis

The following analyses were made at USNRDL: (1) gross sample gamma-

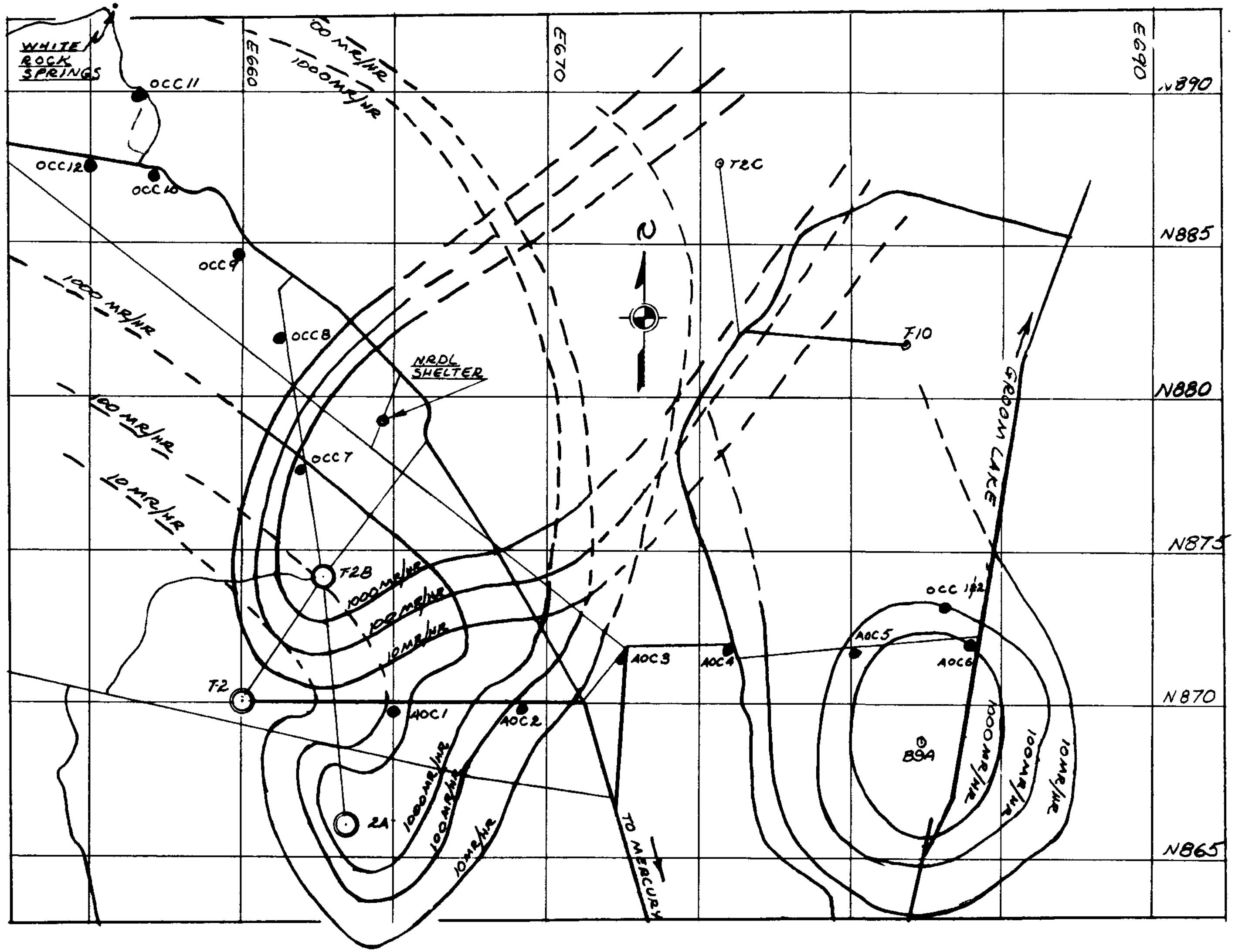

Fig. 3.1--Shots Diablo (T2b), Owen (B9a), and Shasta (T2a) station array and H + 6 Rad-Safe contours.

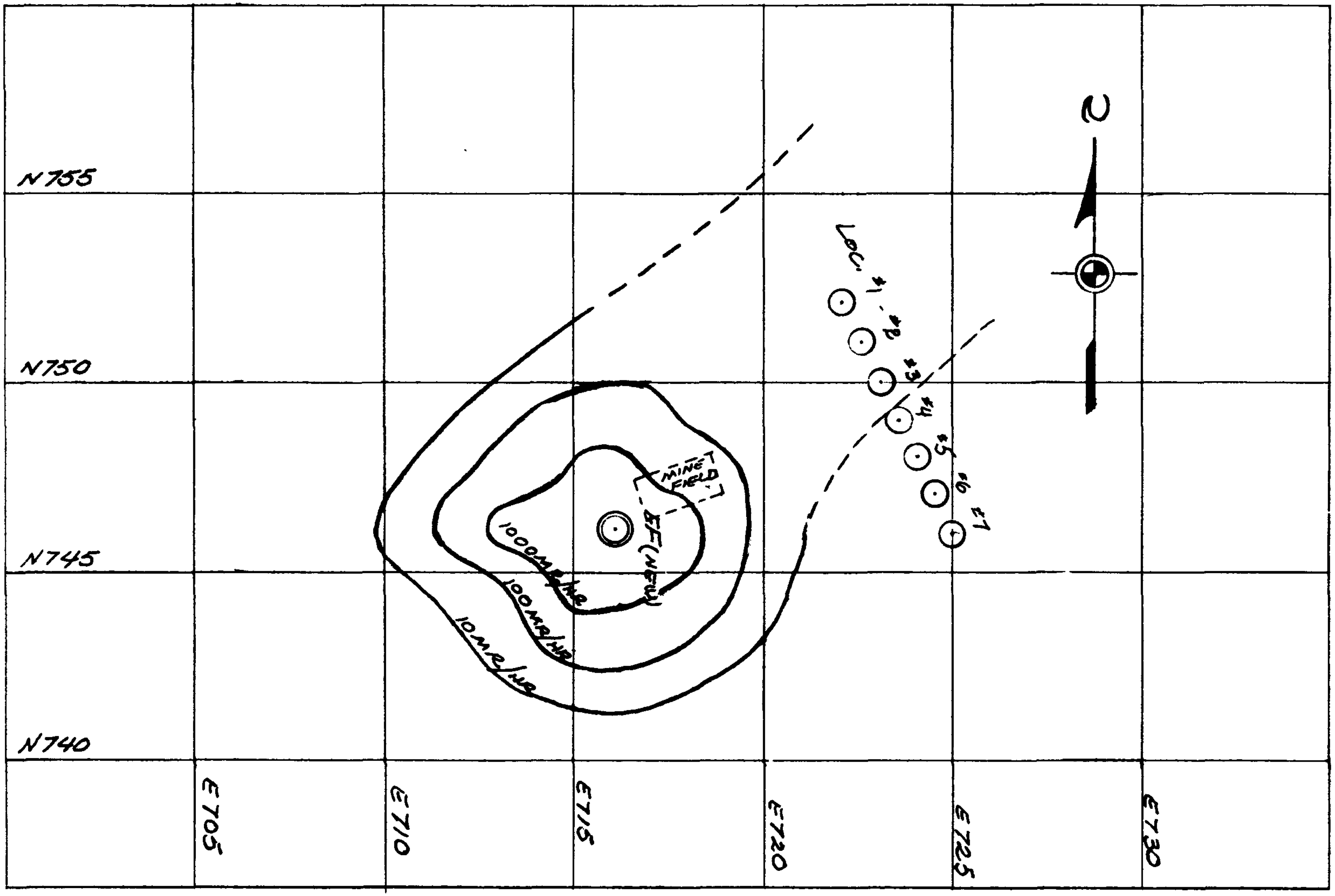

Fig. 3.2—Shot Priscilla station array and H+ 6 contours.

ionization decay, (2) total mass collected, (3) total fissions per sample, (4) gamma-energy spectra, (5) physical characteristics of the individual radioactive particles including size, shape, color, and general surface character, (6) chemical analysis of individual particles for iron and lead, (7) compound analysis of individual particles by x-ray spectroscopy, (8) petrographic analysis of individual particles by thin sectioning, and (9) relative gamma activity of individual particles as a function of size.

Photomicrographic techniques were employed on a number of the particles to permanently document some of these characteristics.

On those shots where the active particles were of similar character to the natural soil particles, the material was first sieved into 10 fractions. Each fraction was then fixed to the back side of single emulsion x-ray film with Krylon for autoradiography. These autoradiographs were then used to identify the active particles. On the tower shots the technique of autoradiography was not necessary for the large-size fractions because of the unique nature of the fallout particles from these detonations.

3.3 RESULTS

Of the four shots documented, two balloon supported and two tower supported, excellent collections were obtained on all but shot Owen, where the fallout was insignificant. Because of the large amounts of soil raised from the surface by the shock wave at the close-in stations, the OCC collections did not consist of pure fallout. However the true fallout was easily distinguished either by radioautographic techniques or by visual observation.

3.3.1 Instrumentation

The fallout collectors, both OCC and AOC, functioned very well over the entire operation. These instruments were 95 per cent successful, the one apparent failure being on shot Shasta wherein an OCC failed to open.

3.3.2 Priscilla Fallout

Preliminary physical characterization of shot Priscilla fallout can be found in Appendix A, where some 100 radioactive particles have been tabulated with respect to their size, relative gamma activity, general shape, and color and remarks have been made regarding their surface character.

In general, the active particles consisted of glassy melted particles, primarily irregular in shape, having the color of natural sand. The size of those measured ranged from approximately 5000 μ down to 50 μ.

Detailed physical, chemical, and radiochemical analyses of Priscilla fallout is now being undertaken, and the results will be published in the final report.

3.3.3 Diablo and Shasta Fallout

Appendix B tabulates some preliminary observations on shot Diablo fallout particles. This tabulation describes the fallout found on the ICC trays exposed at 1-min intervals at the Project 32.3 radiological shelter.

The fallout consisted of large black spheres and irregular particles. After removal of the few visible particles on each ICC tray, the indication of residual activity was less than 1 per cent of the total.

By far the majority of the fallout in all size ranges, down to at least 50 μ, consisted of black glassy looking particles; many were true spheres. Some had small black spheres attached to their surface, but the majority were very smooth. Detailed physical, chemical, and radiochemical analysis of these particles is now being undertaken, and the results will be published in the final report.

The particles collected from shot Shasta have not been observed in detail; however, a cursory observation indicates that they are very similar to the Diablo fallout.

3.4 DISCUSSION

Comparison of fallout particles between a tower shot and a balloon-supported shot can be made between Priscilla and Diablo or Shasta. It was hoped to compare two detonations of equal scaled height (λ) where

$$\lambda = \frac{h}{W^{1/3}} \tag{3.1}$$

h = height of detonation (ft)
w = yield (pounds equivalent TNT)

Preliminary information on yields indicates that this objective was met. It can be concluded that the fireballs from Priscilla, Diablo, and Shasta had nearly the same intersection with the surface.

The fallout particles from Priscilla were distinctly different from those collected at Diablo and Shasta. Not only were their physical characteristics unique but the particles from the tower shots had a much higher specific activity.

Particles from both types of detonation were primarily melted silica; however, the tower-shot material contained a higher quantity of spheres. The black color of the particles from the tower shots was completely missing from the Priscilla fallout, which was entirely the color of desert sand.

Initial thin sectioning of the Diablo particles indicated the black color of the particles was confined to the surface of the particles, their interior being transparent clear melted silica.

These tower-shot particles appear, after cursory examination, to be similar to the particles recovered in past operations[4,5] from tower shots.

The much higher specific activity of the particles recovered from the tower shots as compared to Priscilla suggests that the tower iron is acting as an efficient agent for the removal of the fission products from the fireball.

3.5 CONCLUSIONS AND RECOMMENDATIONS

No conclusions or recommendations can be made at this time.

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Chapter 4

DOCUMENTARY SUPPORT TO PROJECT 32.3

4.1 BACKGROUND

The proper evaluation of the radiological situation at a shelter position requires measurements of the radiation field as a function of time, analysis of fallout collected at the location as a function of time, and knowledge of the types of radiation from the fallout. The measurements and sample collections for Project 32.3 (ITR-1464) were made using standard equipment developed for this purpose.

4.2 PROCEDURE

Instrumentation for documenting the fallout events about the Project 32.3 radiological shelter was accomplished for shots Diablo, Kepler, and Shasta.

4.2.1 Instrumentation

Six OCC's were placed in the vicinity of the shelter. Installation was as described in Sec. 3.2.1. These instruments, however, were manually triggered by hard wire from inside the shelter.

One incremental collector (ICC)[1] was installed at the shelter. This instrument exposed sixty 4 by 4 in. greased collecting trays to the fallout at 1-min increments. Triggering was accomplished manually from inside the shelter.

Two self recording gamma-time intensity recorders (GTIR)[1] were also installed at the shelter to record the gamma ionization rate as a function of time at the shelter. They had a dynamic range of from 3 mr/hr to 400 r/hr and were capable of operating remotely for a period of 7 days. Readout of these instruments was installed in the shelter.

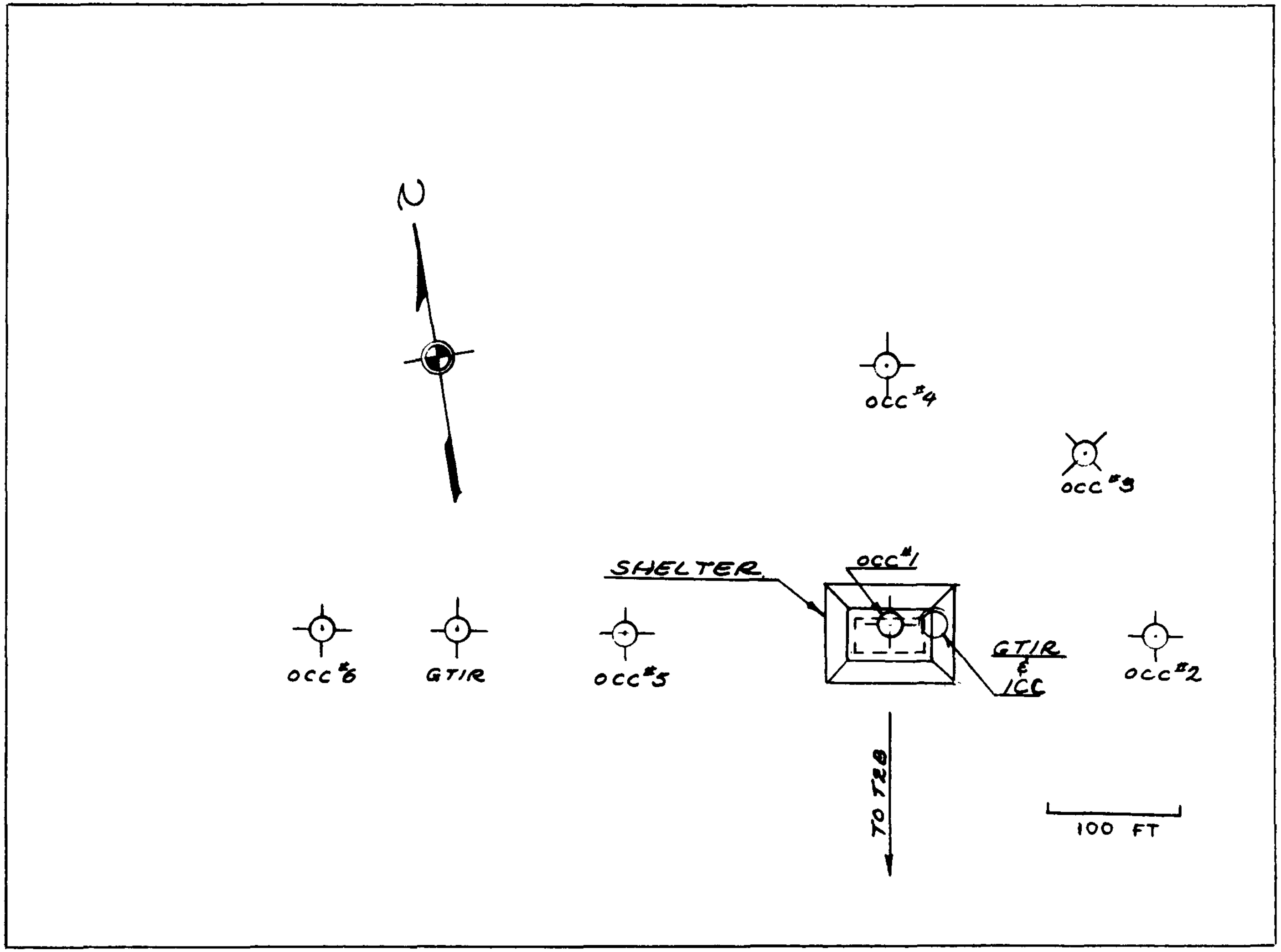

Fig. 4.1--Instrument array for NRDL shelter.

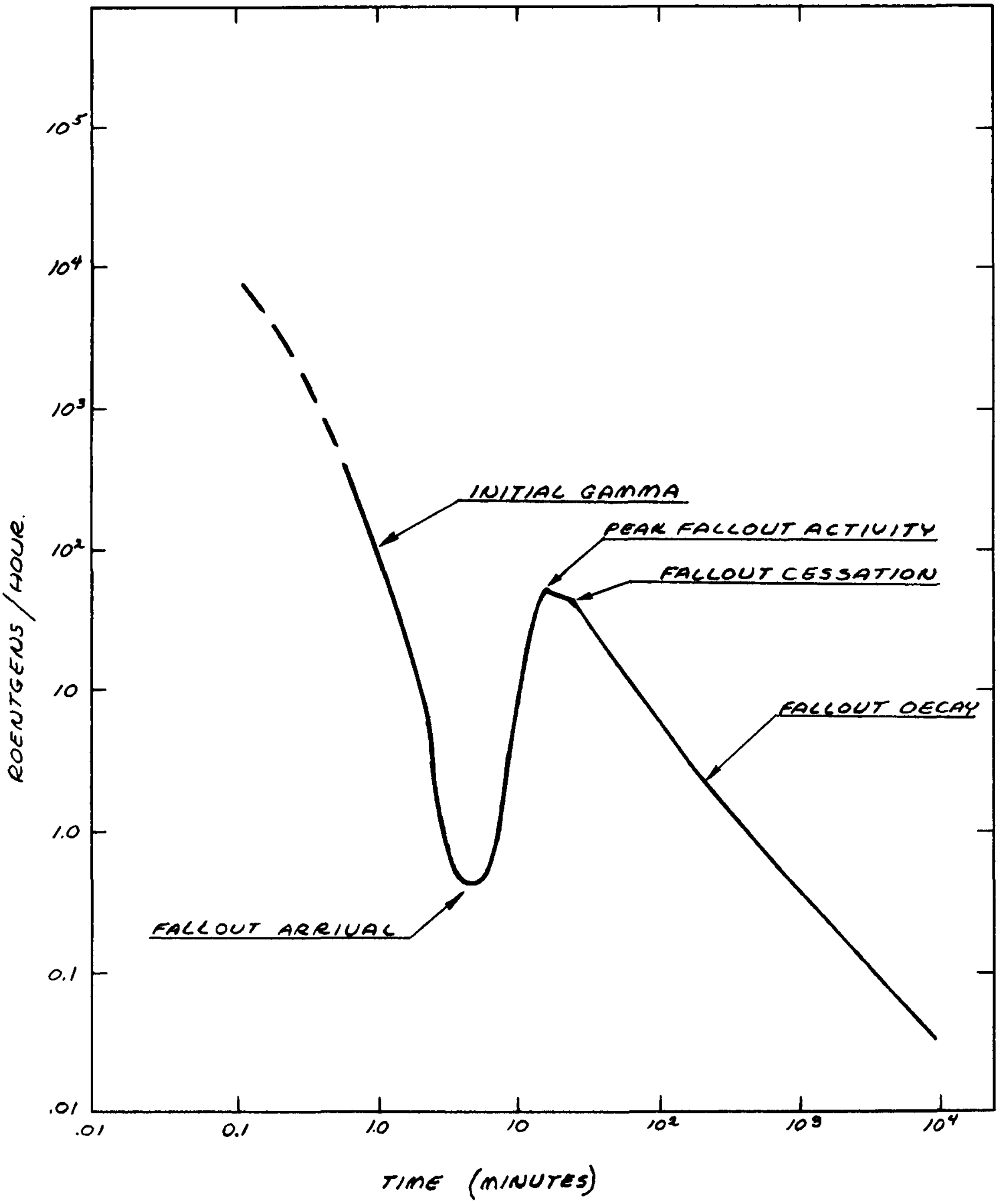

Fig. 4.2--Shot Diablo-gamma activity with time at NRDL shelter.

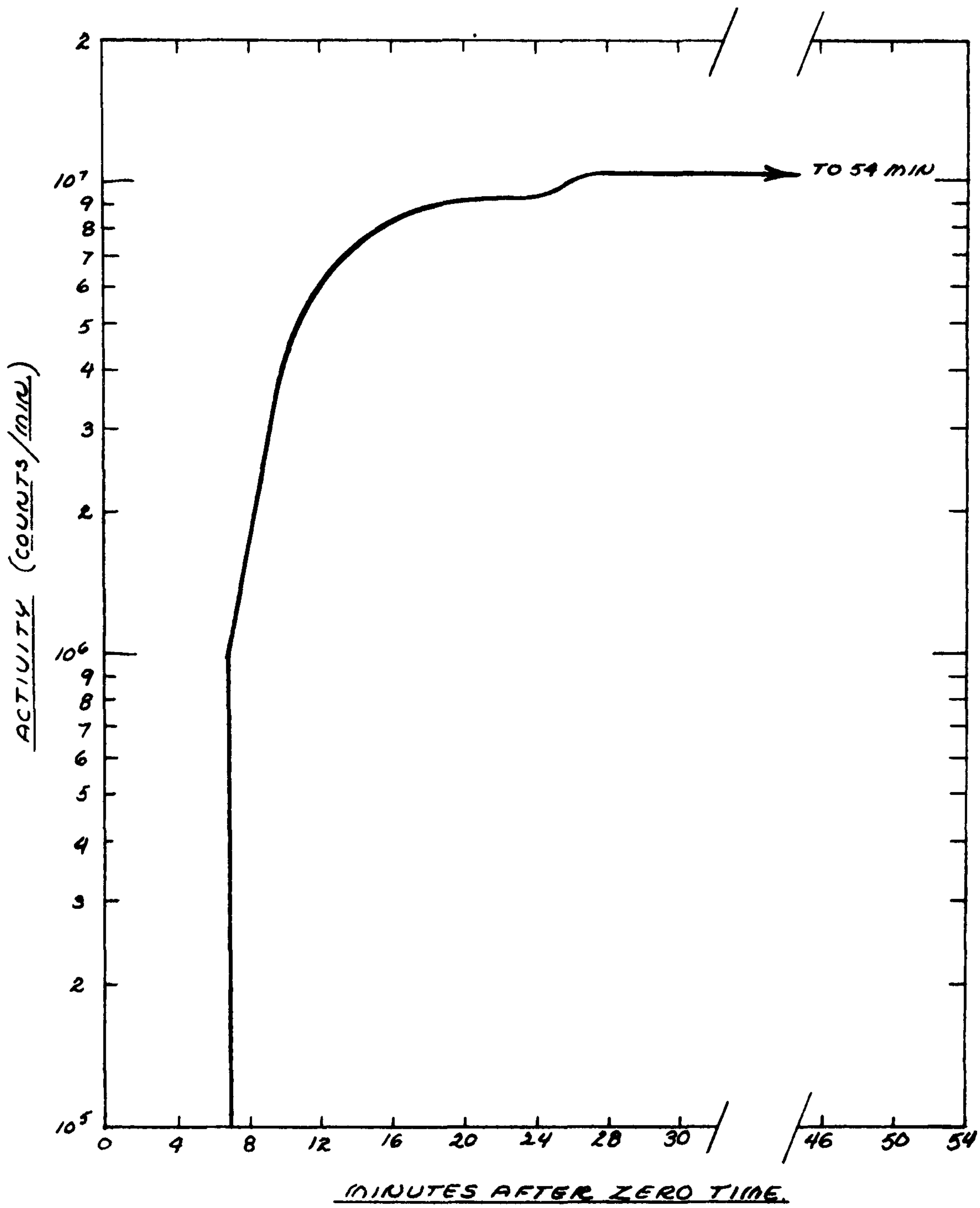

Fig. 4.3--Shot Diablo-cumulative fallout activity from incremental sampler at NRDL shelter.

A recording anemometer was installed on the roof of the shelter with readout in the shelter.

The station array for this instrumentation is shown in Fig. 4.1.

4.2.2 Sample Recovery and Analysis

The OCC samples were recovered and processed as described in Sec. 3.2.2 and 3.2.3 with the exception of one OCC which was recovered by helicopter at H + 20 min for shot Diablo and returned to the Control Point for shipment to the Project 2.2 trailer for early-time gamma spectral analysis.

At USNRDL the OCC samples were analyzed for mass of fallout, gamma activity and decay, and total fissions per unit area.

The ICC trays were counted to determine time of arrival of fallout, time to peak activity, and time of cessation of fallout and its rate of arrival. These data were compared with the records from the GTIR's. These recorders were also analyzed to determine the field decay for a period of several days post detonation.

4.3 RESULTS

The instrumentation placed about the Project 32.3 radiological shelter experienced no failures throughout the operation. All requested data were obtained.

Figure 4.2, for example, is a plot of the gamma radiation as a function of time taken at the shelter during shot Diablo. This plot, obtained by the GTIR, covers the period from H + 0.025 min to H + 4000 min.

Figure 4.3 is a plot of the cumulative activity due to fallout at the shelter during shot Diablo. These data were obtained from the fallout that arrived in the ICC trays, which were triggered every minute.

All remaining data from shot Diablo, as well as all data obtained from shot Shasta, are presently being reduced and will be presented in the final report.

REFERENCE

1. T. Triffet et al., Characterization of Fallout, Operation Redwing, ITR-1317, 17 April 1957, Secret RD.

Chapter 5

FIELD TEST OF PROTOTYPE INSTRUMENTATION

5.1 BACKGROUND

Continued weapons test operations have dictated a continuing instrument prototype development program. Several new instruments and experimental techniques were evaluated for probable use at future test operations.

Many gamma-field measurements require data from various heights above the ground. Use of balloons as supporting devices for instrumentation was evaluated.

Measurement of gamma ionization as a function of time is of great value in understanding the dynamics of the fallout event at any location. A portable light-weight self-contained tape-recording instrument has been developed to satisfy this requirement.

A portable fallout collector is a primary requisite to gamma-field studies. A rugged power-operated self-contained fallout collector has been developed which permits maximum flexibility in installation and operation.

5.2 PROCEDURE

5.2.1 Use of Balloons as Instrument Platforms

Several captive latex balloons were tested under field conditions for use as platforms to support survey meters at various altitudes. Darex N4-24-1750, having a pay load of 22.9 pounds at sea level, and Darex N4-28-2400, having a pay load of 36.2 pounds, balloons were evaluated. The balloons were raised to a fixed altitude, and the survey meters were raised and lowered to the required altitudes by a pulley arrangement. The height of the instrument was determined by a log line from the instrument to the surface.

5.2.2 Fallout Collector

This instrument was employed as the primary collecting device for this Project because of its predicted performance. The OCC's were tested on four shots as described in Sec. 3.2.1.

5.3 RESULTS

5.3.1 Use of Balloons as Instrument Platforms

The use of balloons to suspend instrumentation failed in each attempt. The two main factors responsible were (1) the extreme delicacy of the latex bags, which ripped with little or no effort, and (2) the requirement for very still air for successful operation.

5.3.2 Fallout Collector

Of the twelve OCC's tested, eleven functioned perfectly. One instrument failed to open. At this time the cause of failure is not known.

5.3.3 Gamma-Time Intensity Recorder

The newly developed portable gamma-time intensity recorder was completed at too late a date for testing at this operation.

5.4 DISCUSSION

Unless field conditions are ideal, which they rarely are, the planned use of captive balloons of the type tested should be approached with caution. Better success could probably be obtained with plastic balloons and a design that employed airfoils to give additional lift under windy conditions.

The use of light or blast actuated triggers to open the OCC fallout collectors allowed blast-wave-raised surface dust to enter the collector thereby negating accurate determination of mass of fallout per unit area. Either the employment of a radiation trigger or a delay mechanism on the lid-actuating mechanism is required to eliminate this problem.

5.5 CONCLUSIONS AND RECOMMENDATIONS

No conclusions or recommendations can be made at this time.

Chapter 6

SUMMARY

Because of the tedious nature of the analysis of the fallout samples the results of this Project's work are necessarily limited at this time. Complete analyses will be found in the final report to be published at a later date. Those data reported herein are primarily raw and should be used with caution.

Appendix A

PRISCILLA PARTICLE CHARACTERISTICS

Table A.1--PRELIMINARY CHARACTERIZATION OF SHOT PRISCILLA RADIOACTIVE FALLOUT PARTICLES COLLECTED 7000 YARDS FROM SURFACE ZERO

Particle No.	Size in microns Max.dia.	Min.dia.	Relative gamma activity at H+340 hrs, counts/min	General shape	Color	Remarks
20-A-A	3115	930	11,800	Cylindrical	Opaque, yellow brown	Glassy, opaque with melted bubbly surface projections
20-A-B	1810	1020	430	Bean-like	Cream opaque	Glassy smooth surface with cracks, particle broken, surface appeared melted
20-A-C	2560	2560	3,066	Disc with jagged edges	Opaque, rose grey	Rough disk shape, small bubble on surface may indicate partial melting
20-A-D	1440	1440	24,626	Spherical	Transparent with black specks	Glassy, many small spheres or bubbles on surface, melted
20-A-E	2880	1900	10,650	Rough ellipsoidal	Sand, semi-transparent	Melted surface with glassy bubbly appearance in spots, unmelted interior contains black specks
20-A-F	2320	2090	9,318	Angular	White, semi-transparent	Quartzlike, jagged edges, however, smooth melted surface
20-A-G	1160	1160	1,347	Spherical	Cream, semi-transparent	Melted slightly bubbly appearing surface, grey green inside
20-A-H	2930	2100	25,894	Angular irregular	Sand opaque	Melted, bubbly projections on surface
20-A-I	1395	1350	3,575	Spherical	White, semi-transparent	Melted, internal bubbles
20-B-A	980	980	35,592	Spherical	Transparent, olive green	Nearly perfect sphere, smooth surface interior has bubbles and black specky material
20-B-B	2140	1630	Not counted	Angular	Sand opaque	Very slight indication of partial melting on surface, weak autoradiograph
20-B-C	1720	1580	Not counted	Angular	Cream sand opaque	No indication of melted surface, very weak autoradiograph

20-B-D	1400	1250	Not counted	Angular	Sand opaque	No indication of melted surface, very weak autoradiograph
20-B-E	3720	1250	18,185	Cylindrical	White opaque	Glassy, melted, bubbly surface projections
20-B-F	3720	2320	56,831	Irregular	White, semi-transparent	Partially melted surface, bubbly surface projections, dark green black interior
20-B-G	1670	1070	4,887	Pointed ellipsoidal	White opaque	Melted smooth surface, small bubbles on surface, green black interior
20-C-A	2240	980	Not counted	Rough cylinder	Cream opaque	Partially melted nonglassy surface, many projections on surface, some bubble-like
20-C-B	2560	1400	Not counted	Angular	Cream brown opaque	Partially melted surface, clear transparent spherical projections on surface
20-C-C	1860	1630	Not counted	Agglomeration of spheres	Cream, semi-transparent	Agglomeration of small spheres, some transparent, some opaque, all melted together, green interior
20-C-D	1120	1120	16,772	Sphere	Mottled amber, clear in spots	Perfect sphere, transparent in spots
20-C-E	1160	1160	1,589	Spherical	Mottled amber with clear spots	Perfect sphere with several spherical projections
20-C-G	Missing		10,632	Irregular	Cream brown, semitransparent	Melted surface with many glassy bubble-like projections
20-C-H	4650	1160	23,317	Semidumbbell	Cream brown semitransparent	Melted, bubble-like projections on surface elongated tear drop or semidumbbell shaped
20-C-I	1950	1630	Not counted	Angular	Rose opaque	Slightly melted surface
20-C-J	2460	1540	Not counted	Angular	White opaque	Partially melted, some bubble-like projections on surface
30-A-A	1160	790	Not counted	Bean-like	Cream transparent	Appears broken in two; one half missing glassy throughout, smooth surface
30-A-B	930	930	1,575	Sphere	Mottled amber with clear spots	Perfect sphere, glass, transparent

Particle No.	Size in microns Max.dia.	Min.dia.	Relative gamma activity at H+340 hrs, counts/min	General shape	Color	Remarks
30-B-A	980	930	2,146	Spherical	Mottled amber with clear spots	Glassy transparent, near perfect sphere
30-B-B	1400	980	Not counted	Spherical	Mottled amber with clear spots	Glassy transparent sphere with two large bubble-like projections
30-B-C	840	790	Not counted	Angular	White, semi-transparent	Full of internal bubbles, glassy
30-B-D	1210	880	Not counted	Spherical	Mottled amber with clear spots	Sphere with many small bubble-like projections
30-B-E	1630	1160	Not counted	Angular	Amber and milk color	Broken particle, glassy-inside porous with air bubbles, amber color external, milk glass inside
30-B-F	980	980	8,484	Sphere	Mottled amber with clear spots	Glassy perfect sphere, transparent
30-B-G	880	880	1,772	Sphere	Mottled amber with clear spots	Glassy perfect sphere, transparent
30-B-H	1210	1120	Not counted	Spherical	Cream opaque	Melted surface, some bubble-like projections on surface
30-B-I	---	---	Not counted	Ellipsoidal	Amber opaque	Melted, small bubble-like projections on surface, glassy
30-B-J	1070	1070	Not counted	Sphere	Mottled amber with clear spots	Sphere with few bubble-like projections on surface, transparent
30-B-K	1400	880	Not counted	Bean-like	Mottled amber with clear spots	Melted glassy, bubble-like projections on surface
30-B-L	930	930	Not counted	Sphere	Cream opaque	Glassy melted, few small bubble-like projections on surface

30-B-M	835	835	19,789	Sphere	Mottled amber with clear spots	Perfect sphere, transparent, very large autoradiograph
30-C-A	1120	1120	Not counted	Angular	Whitish grey	Semimelted appearance, not glassy
30-C-B	2100	1070	23,376	Bean-like	Amber, transparent	Glassy, several large bubble-like projections, 90 μ black sphere imbedded in surface
30-C-C	1070	930	Not counted	Angular	Sand opaque	Unmelted surface, weak autoradiograph
30-C-D	1630	930	Not counted	Angular	Sand and black opaque	Slightly melted, not glassy, very weak autoradiograph
30-C-E	2320	930	Not counted	Irregular	Amber, transparent	Melted surface, many large bubble-like projections, glassy
30-C-F	1170	930	Not counted	Angular	Rose sand opaque	Semi-melted, not glassy, several bubble-like projections on surface
30-C-G	930	930	5,524	Sphere	Black opaque	Smooth sphere
30-C-H	790	790	723	Sphere	Mottled amber with clear spots	Melted transparent glassy sphere
30-C-I	1630	1160	Not counted	Tear drop	White amber, transparent	Broken tear drop, glassy
30-C-J	1070	740	Not counted	Angular	White opaque	Cavernous, glassy
30-C-K	1530	840	3,784	Bean-like	Amber, transparent	Glassy, several bubble-like projections on surface
40-A-A	605	560	1,252	Spherical	Cream opaque	Melted, glassy, several rough bubble-like projections on surface
40-A-B	560	560	538	Angular	Cream opaque	Angular sphere, melted surface, not glassy, rock structure still apparent
40-A-C	790	465	Not counted	Irregular	Cream opaque	Melted glassy blob made up of many bubble-like spheres all fused together
40-A-D	745	465	Not counted	Irregular	Cream opaque	Elongated glassy, blob, smooth surface
40-A-E	1020	510	Not counted	Irregular	Cream, semi-transparent	Glass, melted, appears to be a sphere that popped while still in a liquid state

Particle No.	Size in microns Max.dia.	Min.dia.	Relative gamma activity at H+340 hrs, counts/min	General shape	Color	Remarks
40-A-F	790	700	Not counted	Angular	White opaque	Not glassy, unmelted, good autoradiograph
40-A-G	840	790	Not counted	Angular	White, semi-transparent	Glassy, melted, cavernous, weak autoradiograph
40-A-H	700	560	Not counted	Angular	Cream trans-parent	Melted surface, some bubble-like projections
40-A-I	1020	600	Not counted	Irregular	Cream trans-parent	Melted glassy blob, appears to be many bubble-like spheres fused together
40-A-J	700	700	Not counted	Irregular	Cream trans-parent	Melted glassy irregular sphere, perhaps popped, very large autoradiograph
40-A-K	1530	790	Not counted	Irregular	Cream trans-parent	Melted glassy blob with bubble-like projection on surface
50-A-A	600	420	Not counted	Irregular	Cream trans-parent	Melted glassy blob
50-A-B	650	510	Not counted	Irregular	Whitish specky transparent	Glassy blob
50-A-C	700	465	Not counted	Irregular	Amber, trans-parent	Appears to be a hollow-broken cylinder closed at one end with a bubble
50-A-D	930	465	Not counted	Angular	Rose sand opaque	Not glassy, slightly melted surface, weak autoradiograph
50-A-E	420	420	Not counted	Spherical	Cream opaque	Melted, glassy with bubble-like projection, very large autoradiograph
50-A-F	840	465	Not counted	Angular	Rose cream opaque	Unmelted sand particle, very weak autoradiograph
60-A-A	790	232	Not counted	Cylinder	Clear trans-parent	Appears broken on end and hollow or tube-like, very large autoradiograph
60-A-B	465	280	Not counted	Irregular	Clear, trans-parent	Glassy blob
60-A-C	560	330	Not counted	Angular	White opaque	Rounded angular, melted surface on one end

60-A-D	510	330	Not counted	Irregular	Amber transparent	Melted glass blob
60-A-E	465	330	Not counted	Irregular	Clear transparent	Glass blob
100-A-A	280	230	Not counted	Irregular	Cream opaque	Semi-melted bubble-like surface
100-A-B	465	185	Not counted	Irregular	Dark opaque	Striated elongated particle, melted surface in spots
100-A-C	280	140	Not counted	Irregular	Clear transparent	Melted, glassy blob
100-A-D	330	280	Not counted	Angular	Yellow opaque	Not glassy, melted surface
100-B-A	185	93	Not counted	Angular	Cream opaque	Not glassy
100-B-B	325	185	Not counted	Angular	Cream opaque	Not glassy
100-B-C	280	185	Not counted	Angular	Cream opaque	Melted surface, bubble-like projections
100-B-D	330	280	Not counted	Spherical	White opaque	Unmelted appearance
140-A-A	375	375	Not counted	Irregular	Cream opaque	Melted blob with bubble-like projections on surface
140-A-B	93	93	Not counted	Ellipse	Opaque	Unmelted
140-A-C	280	140	Not counted	Irregular	Transparent	Glassy elongated blob
140-A-D	140	140	Not counted	Irregular	Transparent	Glassy blob
200-A-A	93	93	Not counted	Spherical	Amber transparent	
200-A-B	140	93	Not counted	Irregular	Transparent	Elongated glassy
200-A-C	140	93	Not counted	Irregular	Cream opaque	Unmelted
200-A-D	140	93	Not counted	Ellipsoidal	---	Glassy
200-B-A	93	46	Not counted	Spherical	Transparent	Glassy
200-B-B	46	46	Not counted	Irregular	Transparent	Glassy blob
W-A	560	325	Not counted	Irregular	Amber opaque	Melted blob
T-A	1300	1020	Not counted	Spherical	Amber transparent	Bubble-like glassy projections on surface
T-B	232	185	Not counted	Spherical	Cream opaque	Bubble-like glassy projections on surface
Y-A	600	325	Not counted	Irregular	Cream opaque	Melted glassy

Appendix B

DIABLO PARTICLE CHARACTERISTICS

Table B.1--PRELIMINARY OBSERVATIONS OF DIABLO ICC TRAYS

Time after zero, min	Activity, counts/min	Remarks
0	3	Sand and some large gravels
1	0	Fairly clean, some natural fines
2	13	Clean with low background
3	17	Clean with low background
4	14	Clean with low background
5	0	Clean with low background
6	97	Clean with low background
7	1,026,000	1 large black smooth teardrop
8	47	Clean with low background
9	1,671,000	2 large black spheres with small spheres attached; several fragments elsewhere
10	1,117,000	1 large black melted blob
11	1,688,000	6 smaller spheres, one blob, several fragments, all black
12	488,900	1 black sphere
13	163	Clean with low background
14	1,208,000	3 spheres, two black with red tinge, one white glass, some fragments
15	117	Black fragments
16	938,800	1 large black sphere, some black fragments
17	541,000	1 sphere with projections, many fragments, all black
18	97	Some black fragments
19	434,600	1 black sphere, few black fragments
20	60	Clean with low background, one fragment
21	70	1 black fragment
22	33	Several black fragments
23	168,000	1 small black sphere

Table B.1--PRELIMINARY OBSERVATIONS OF DIABLO ICC TRAYS (Cont'd)

Time after zero, min	Activity, counts/min	Remarks
24	308,900	1 small black sphere
25	393	Several black fragments
26	383,400	1 sphere, two melted irregular, some fragments, all black
27	518,300	2 small black spheres
28	27	Clean with low background
29	0	Few black fragments
30	6	1 black fragment
31	10	Few fragments
32	17	Some black fragments
33	0	Few black fragments
34	0	Black sphere imbedded in clear glass blob, several fragments
35	0	Some black fragments
36	0	Clean with low background
37	20	Few black fragments
38	0	Clean with low background
39	0	Some small irregular black particles
40	17	Small black particles or fragments
41	20	Small black particles, a few clear melted looking particles
42	34	Black fragments
43	167	High particle background as if high wind had come up
44	467	Again high particle background
45	0	Clean with low background
46	22,460	1 large semimelted particle grey transparent
47	0	Clean with low background
48	0	Clean with low background
49	0	Several black fragments
50	0	Clean with low background
51	0	1 black fragment
52	47	Clean with low background
53	34	2 black fragments
54	281	High background, many black particles

Note: Samples counted 7/16/57 corrected for decay to 1200 PDT.